JOHNSON SPACE CENTER

THE HOME OF HUMAN EXPLORATION

Johnson Space Center; Houston, TX – White Sands, NM

Ellington Field Houston, TX

Neutral Buoyancy Lab Houston, TX

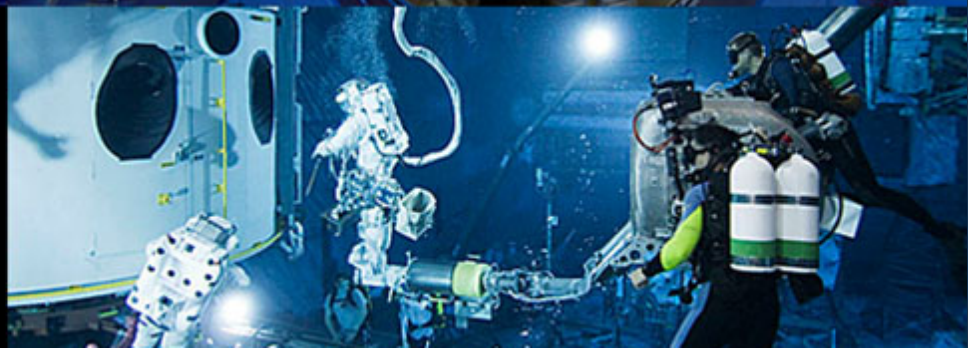
White Sands Test Facility, NM

National Aeronautics and Space Administration

NASA

JOHNSON SPACE CENTER

Human Integrated Exploration Systems



Process for Assessing Climate Risks to Center Assets

- How we assessed Center assets to determine climate risks:

  Lessons learned from past hurricanes, tropical storms and droughts
  Regional wind/flood studies
  Technical discipline analysis – corporate knowledge
  Contractor team input (field reports, etc..)
  Facility Manager Program input

- Effort is complete, on-going, just starting?

  On-going.

- How we prioritized our list of assets at risk:

  Mission critical
  Recommendations from studies
  Contractor "flash" reports
  Flood Zones vs. Assets (tunnels, 200 area)
  Failures generate inspections (curtain walls, foundations)

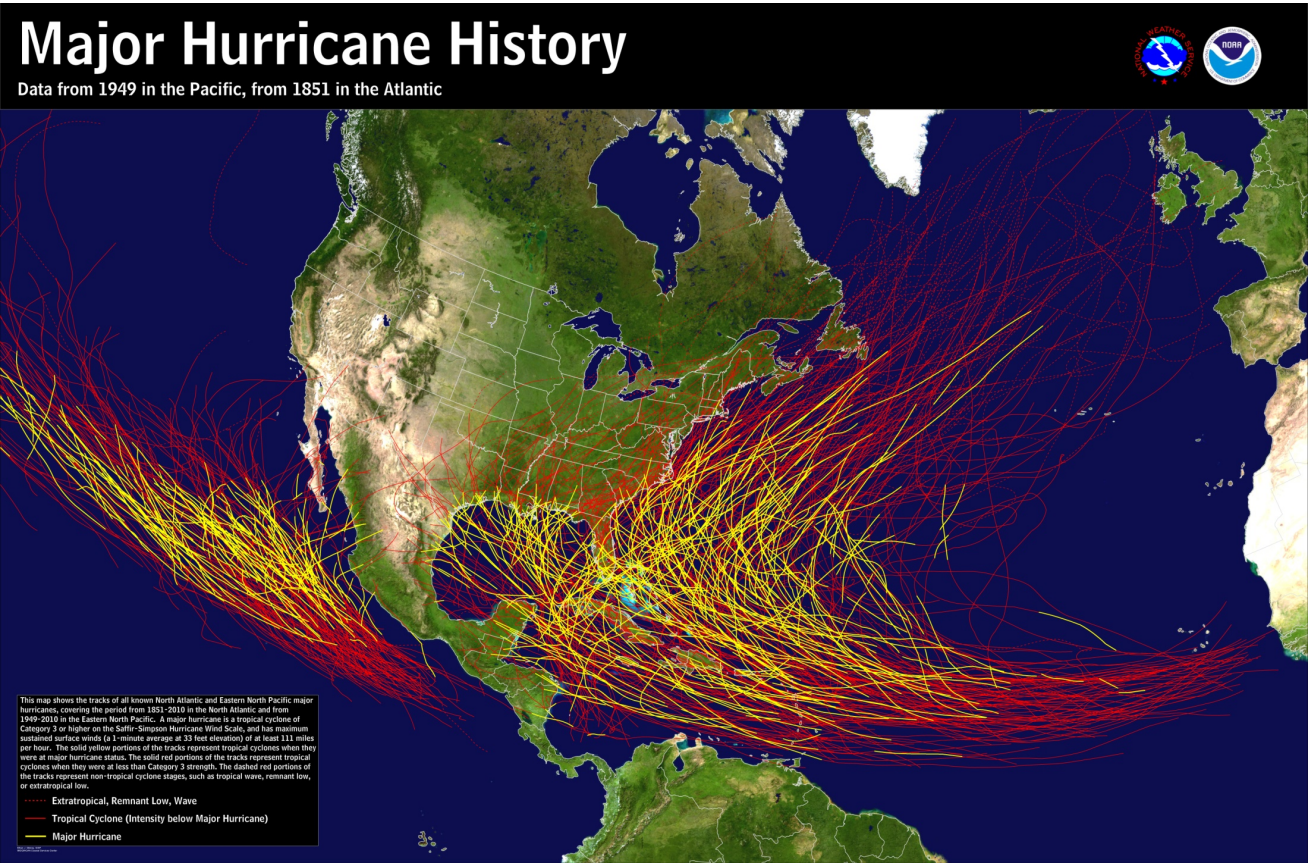


Image source: http://www.nhc.noaa.gov/climo/
Hurricane Ike damage images courtesy NASA

June 1 through November 30 is “hurricane roulette” season for Atlantic Basin and Gulf of Mexico – several NASA centers at risk

Climate Variables Impacting JSC

Climate Variable	Potential Impacts
Sea Level Rise	Exacerbated flooding from storm surges; reduced emergency response capabilities. Increased salinity impacts to drinking water resources and habitats
Coastal Flooding	Impacts to wastewater treatment plants on the coast; damage to infrastructure; changes in shoreline habitats; overloading of stormwater management system
Overall Increased Temperature	Increased cooling costs in the summer; decreased heating costs in the winter. Changes in plant and animal cycles, including pest and disease vector species
Increased Number of High Temperature Days	Potential for damage to infrastructure materials; potential for limiting work and recreation outdoors; increased health problems related to heat stress
Precipitation Changes	Increased flooding from extreme precipitation events; increased risk of drought as temperatures rise; habitats affected by fluctuating groundwater levels

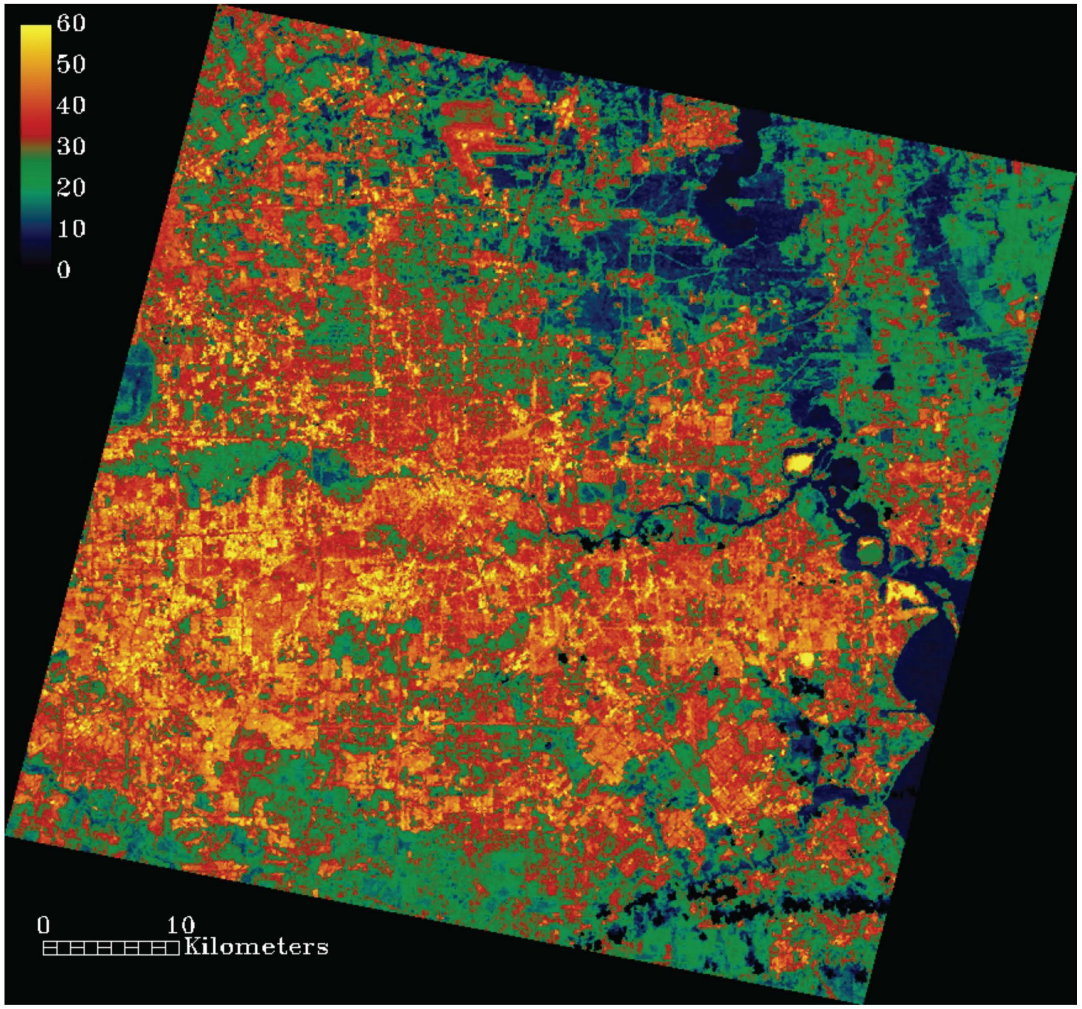
Qualitative impacts

Climate Variables				
Variable	**Baseline**	**2020s**	**2050s**	**2080s**
Average Temperature	70.5°F	+1.5 to 2.5°F	+2.5 to 4.5°F	+3.5 to 7°F
Annual Precipitation	54 in	-5 to +5%	-15 to +5%	-15 to +5%
Sea Level Rise	NA	+2 to 3 in	+5 to 9 in	+11 to 20 in
Sea Level Rise – Rapid Ice Melt Scenario (See Rapid Ice Melt text box for more detail)	NA	~4 to 8 in	~17 to 26 in	~40 to 55 in

Temperature and precipitation projections reflect a 30-year average centered on the specified decade; sea levels are averages for the specific decade. The baseline for temperature and precipitation is the most complete 30-year data period centered around the 1980s; the baseline for sea level is 2000 – 2004. Temperature and precipitation data are for Houston, TX (Hobby Airport) and sea level data are for Galveston, TX. Temperatures are rounded to the nearest half degree, precipitation projections to the nearest 5%, and sea level rise to the nearest inch. Shown are the central range (middle 67% of values from model-based probabilities) across the GCMs and GHG emissions scenarios. Data are from the NOAA National Climatic Data Center.

Modeled quantitative impacts

JSC/Houston-Galveston “Heat Island Effect”



HICO water band (R), carotenoid reflectance (G), anthocyanin (B) [right]; visible RGB image [left]. 5/5/11

Visible RGB astronaut photograph from ISS, 7/31/10, 400 mm lens

ASTER LST (C), 9/14/06

Specific Risks

Specific Infrastructure Assets at Risk (and why we're concerned)

- **Utilities infrastructure** via tunnel system (site infrastructure)

  Concern: Flooding and long recovery time to steam and electrical systems

- **200 area of campus & B37** (Human Health & Performance) Astronauts health care systems research & development for countermeasures, neurosciences, cellular biology, cardiology, etc…)

  Concern: Low elevation subject to flooding and storm surge

  Note: Low elevation partially due to subsidence from using well water in the 60's-70's. Site elevation fell approximately 1 foot

- **Mission critical assets**; Disruption to real-time mission support

- **Power loss – supply** (ESPC project @ JSC/SCTF)

  Concern: Rolling blackouts impact Center Plants operations, drought caused numerous overhead line failures from salt accumulation, MCC back up power building 48 is obsolete and unreliable.

- **Water – gray water circulation**

  Concern: State of Texas water resources are being depleted from the drought resulting in mandatory water rationing. Also drought conditions resulted in extensive water line breaks from expansive clay soils.

Other Important Non-Infrastructure Risks?

- Other Climate Risks to Natural Resource or Community assets that have the Center's or public's attention:
  - Regional economic impact with JSC shutdown
  - Water supply – State drought conditions
  - State electrical supply vs. summertime demand

Information Gathering or other Efforts to Assess Risk or Plan Adaptation

What we're doing now:

- Gathering information on…
  - Sea level rise models; flooding
- Researching…
  - Climatology trends with local experts
- Evaluating possible adaptation strategies…
  - Engineering and land use approaches to built systems
- Partnering with…
  - Regional entities to share adaptation strate

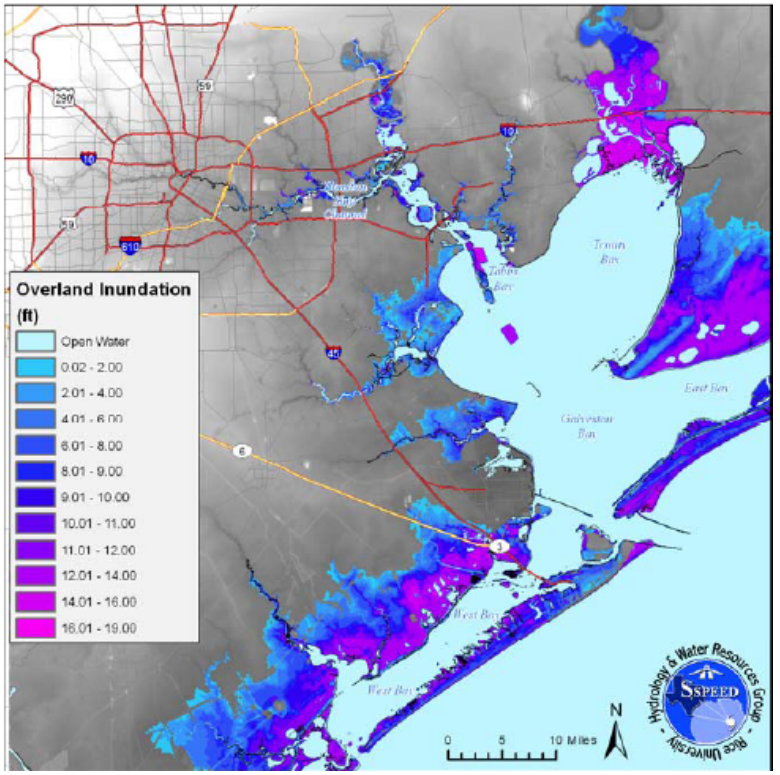
Research/Education and Collaborative Activities

❖ **University of Houston/UC Berkeley National Center for Airborne LiDAR Mapping (NCALM)**

- Space Act Agreement in work to establish regional remote sensing center with JSC; natural fit with CASI activities
- NASA Science Innovation Fund grant awarded to support initial LiDAR/hyperspectral data collection in Rollover Pass area of Bolivar Peninsula, will obtain detailed near shore bathymetric mapping and facilitate collaboration with Rice University SSPEED group

❖ **Regional Remotely Sensed Data Now Available to JSC Center Ops**

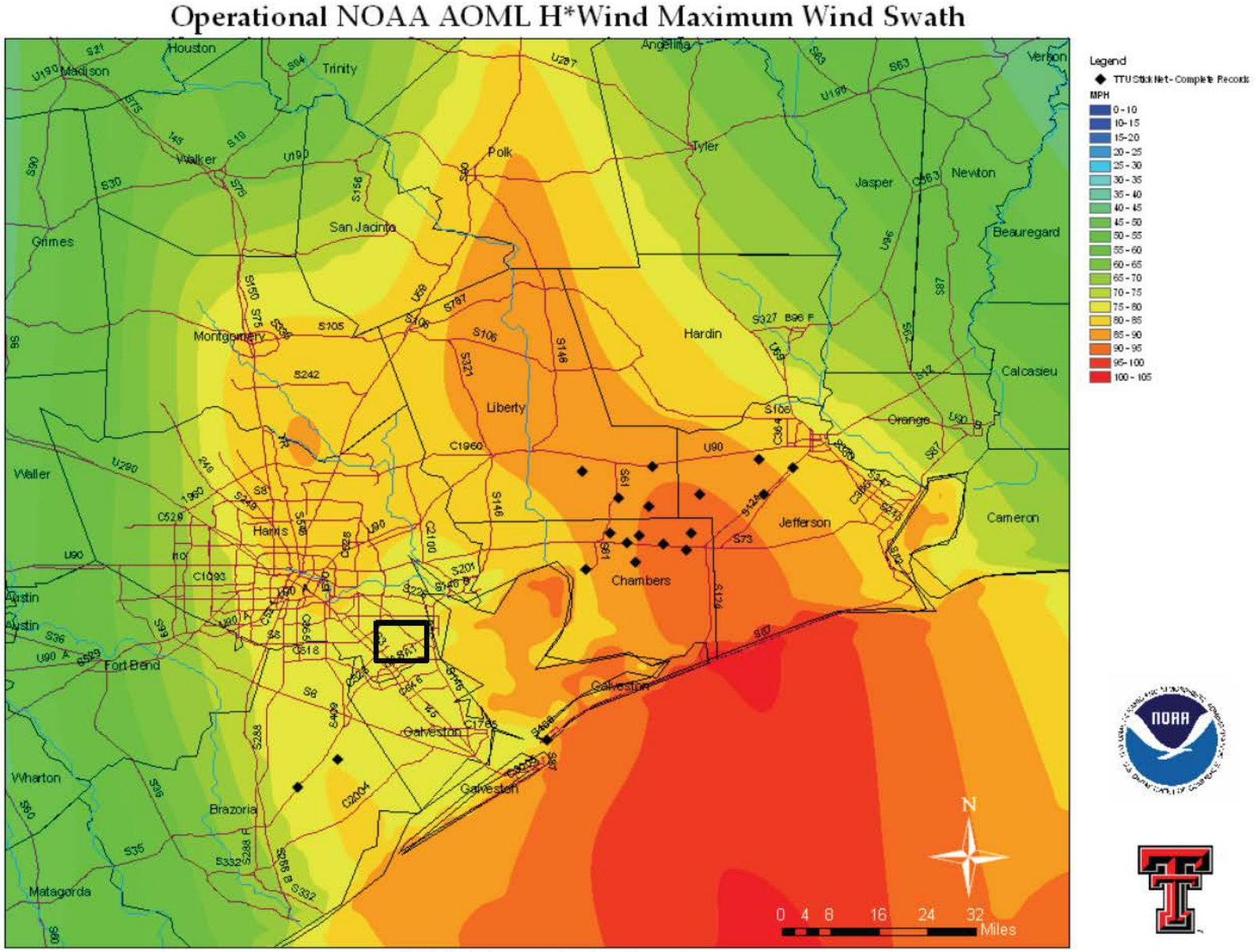
- Landsat multispectral data (1972 – 2011, multi-season) for Galveston Bay region
- ASTER visible through thermal infrared multispectral data (2001-2010) for JSC area; MASTER airborne superspectral data (1999)
- NAIP very high resolution airborne visible/near-infrared data (2004-2010) for Galveston Bay region
- Hyperspectral data (HICO, Hyperion) available for discrete parts of Galveston Bay/JSC areas



❖ **Collaborations in Work**

- Rice University Severe Storm Prediction, Education, and Evacuation from Disasters Center (SSPEED)
  - detailed “what if” modeling of storm surge, flooding, and hurricane impacts in the Galveston Bay area
- Armand Bayou Nature Center
  - bring JSC remote sensing expertise to field and laboratory exercises
- University of Houston Geo-sensing program
  - establishing joint projects with graduate students focused on climate adaptation

Hurricane Ike, 9/9 – 9/15/2008



H*Wind wind speeds given in miles per hour

JSC Flooding Simulation, 12 feet mean lower low water

Flood | Layers

Data View: Johnson Space Center

Reference: Clear Lake

Water Datum: MLLW

Water Level: 12 ft

- or -

3.658 m

Building	Est. Interior Water Level (ft)
229	5
207IB	0.49
223B	0.49
	0.49
223A	0.49
204	0.49
207IA	0.49
231	0.34
259	0.09

Interactive flood model interface developed by LaRC GIS team; http://jsc-ja-gis2.ndc.nasa.gov/jscmaps/floodtool/

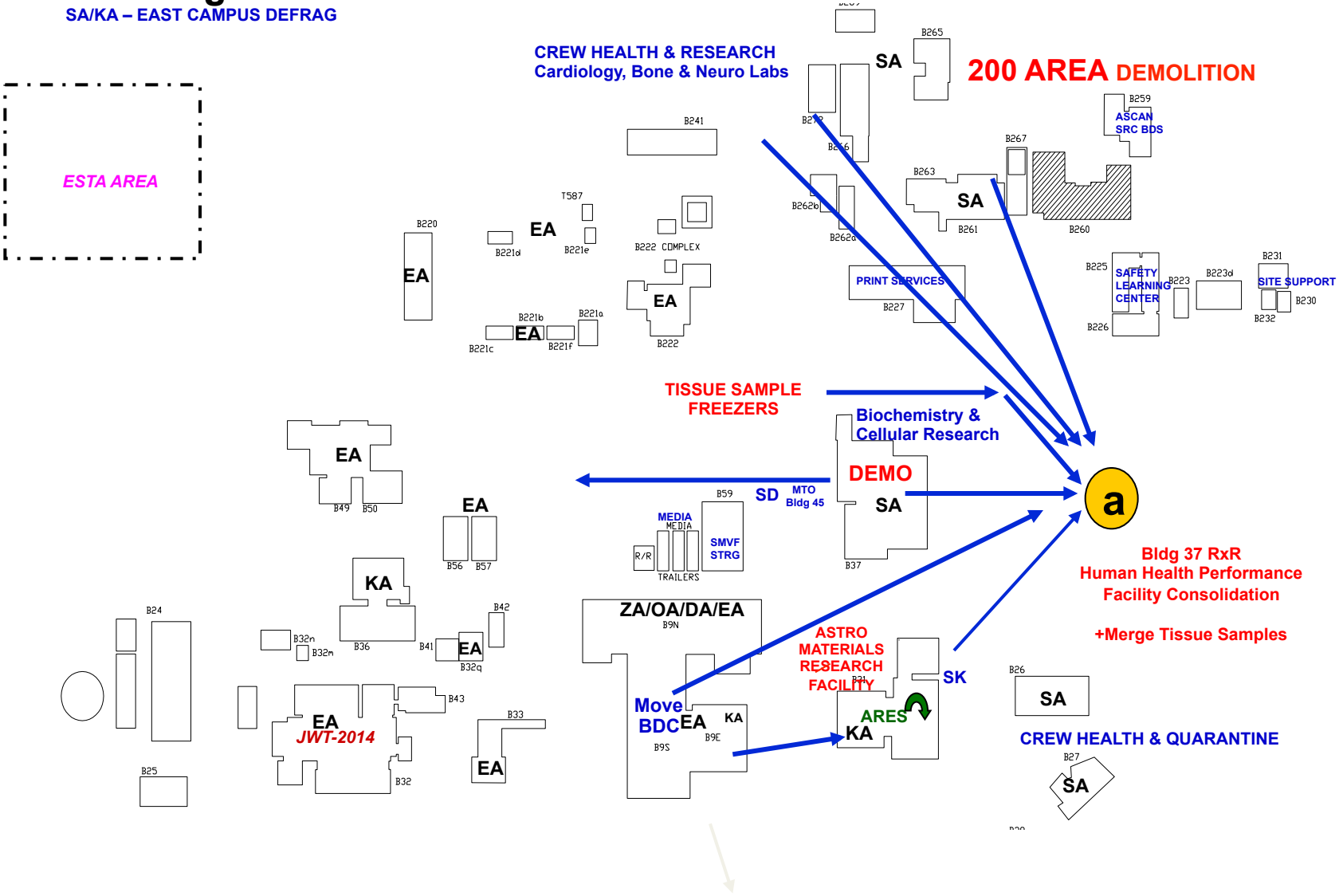
Example Flood Impact Analysis


University of Houston
Clear Lake
Armand Bayou
Adaptation Strategy
Land Use
Mix Use
Residential
Development
Center Support
Services
Energy Systems
Test Area
Morale
& Wellfare
Areas
Demolish
consolidate @
Core Campus via
Recap RxR & Tactical Plng
Multi-Family
Development
200 Area
Exploration Systems
Test Range & Buffer Zone
Space Center
Intermediate
Saturn Lane
CCISD
Main Entrance
Nassau Bay
Space Center
Houston Visitors Center
Clear Lake

SLSD/HRP Defragmentation Plan

SA/KA – EAST CAMPUS DEFRAG

Adaptation Strategy via Integration of Master Planning, Tactical Planning & Recap

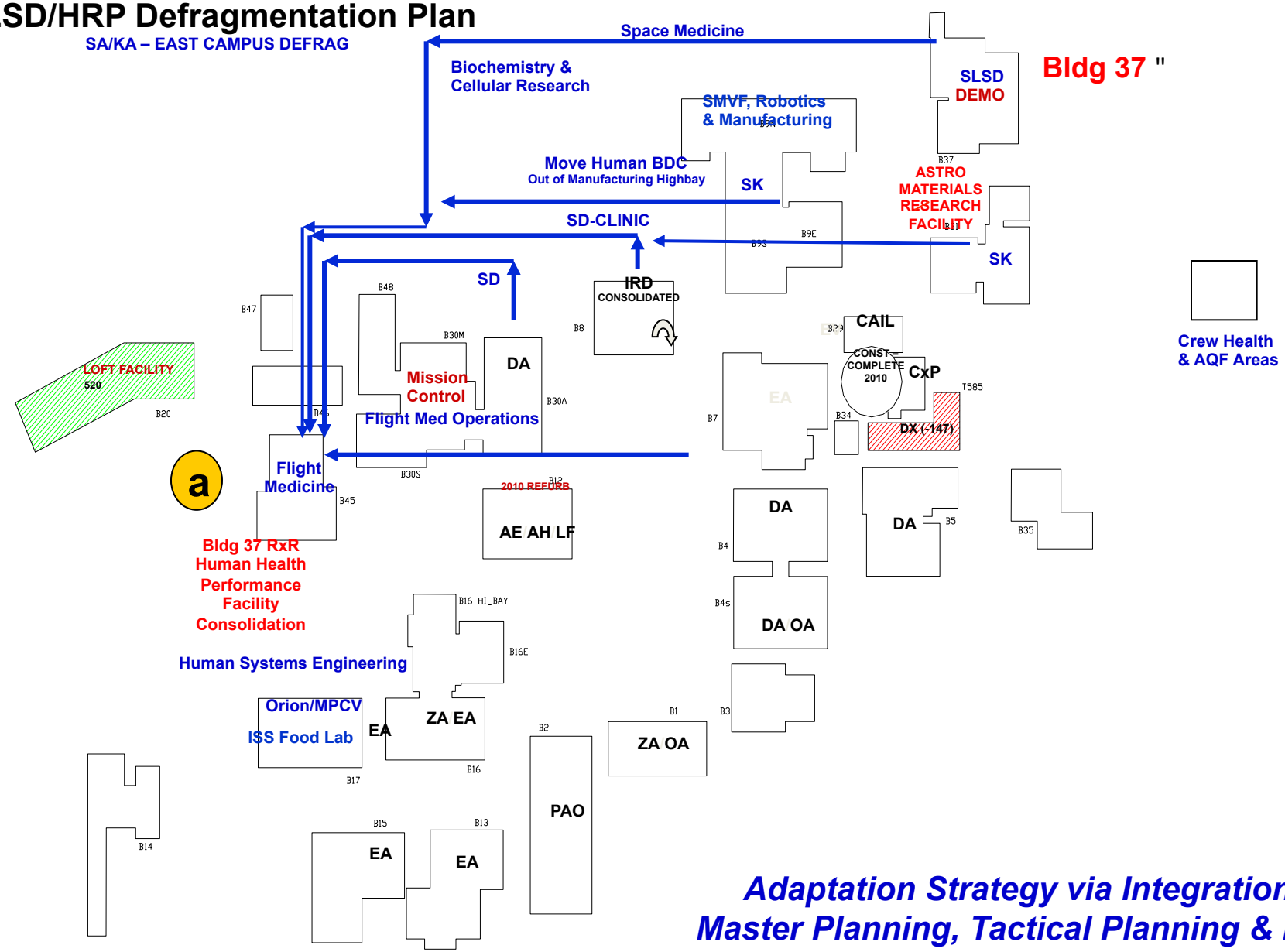


Jan-June 2010	July-Dec 2010	Jan-June 2011	July-Dec 2011	Jan-June 2012	July-Dec 2012	Jan-June 2013	July-Dec 2013

a B37 RxR w/200 Area Demolition

SLSD/HRP Defragmentation Plan

SA/KA – EAST CAMPUS DEFRAG



Adaptation Strategy via Integration of Master Planning, Tactical Planning & Recap

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a B37 RxR w/200 Area Demolition

Adaptation Strategy; **Built Systems - AE Requirements**

Adding the following requirements to our AE design requirements to reduce Climate Change Risks:

- Temperature - Explore Shading Techniques and Evaluate Building Orientations for Solar Control.

- Flooding – Make sure to site and build buildings out of the 100 Year Floodplain Level. Design structures and use products to improve flood resilience.

- Water Resources – Design for maximum water efficiency, Investigate use of (sustainable drainage systems, rainwater harvesting/storage systems and grey water recycling).

- Energy Resources – Design for maximum energy efficiency, explore use of renewable energy sources, explore use of green roofs, cool roof/ building/pavement materials.

Adaptation Strategy; **Built Systems**

Building 31N lunar rock sample and meteorite Sample Return Vault is one example of climate adaptation:

- vault is designed to withstand major hurricanes and tornadoes

- vault is airtight to counter threat of rising water

- building floor level is 27 feet above mean sea level

3Building 1N Lunar Sample Vault

Challenges and Accomplishments

- Our biggest challenge thus far has been:
  - Budget related to funding of projects and/or recap program
  - Emergency Repair due to failures

- Our best accomplishment thus far has been:
  - Tunnel project hardening
  - MCC flood mitigation project
  - Energy savings performance contract
    - Emergency stand alone power during site outage to support:
      - Mission critical assets, data centers, gas/water supply

Back up info


CENTER OPERATIONS
DIRECTORATE
FOUNDATION
FOR MISSION SUCCESS

Energy Saving Performance Contract @ SCTF & NBL

This project explores and implements opportunities for renewable systems and technologies, as well as, high efficiency energy and water conservation measures and technologies thereby reducing our carbon footprint. Each of these ECM's reduces the draw on (demand) or conserves the energy systems which are affected by climate change.

- Significantly more efficient Chiller replacements at the SCTF
- Heating Ventilating and Air Conditioning upgrades
- Building envelope upgrades
- Lighting upgrades
- Solar thermal water heating for the astronaut training pool at the SCTF NBL
- Additional metering to support Measurement & Verification (M&V)
- Water use reductions
- Other technologies that will have a significant impact in reducing long term energy consumption without compromising JSC's mission
- Building Automation Systems/Energy Management Control Systems

Climate change is also a key element when considering our site locations. We are factoring these into our Environmental Assessments. The location, orientation, elevation, and height is being taken into consideration when planning the building site.

Energy Management and Control System (EMCS) Changes

- Obtained access to EMCS set points and limits. This new capability allows us to review for future tracking and control related to climate adaptation
- Modified and started tracking these set points to gather data to see how outside air is affecting our systems.
- Upgraded all the chillers in building 28 to allow this tracking and control ability (see screen shot on chart to follow), and we are in the process of updating the chillers in building 24.
- Modified the specifications and design on The Building #24 Cooling Tower Controls Upgrade Project to review climate adaption as part of the new PLC controls.
- Working with our Energy Management Contractor, Honeywell, to upgrade their controllers to allow similar monitoring and adaptive capability in the building HVAC controls – we have added wording to this regard to the new energy management contract.

Combined Heat and Power Plant

- Replacing our current point sources for Green House Gas (NOX) emissions (the boilers) with a newer and cleaner source for heating.

- Reducing our emissions with the planned FY15 Replace Emergency Generator System in building 48.
  - We are reducing the generator capacity from almost 10 MW to 5MW. This reduces the need for load banking runs which further will reduce the Green House Gas (NOX) emissions.